STUDYING THE EFFECT OF DIFFERENT ADDITIVES ON PHYSICAL AND MECHANICAL PROPERTIES OF MORTARS

By

Eng/ Amr Ramzy Abdelghany Attia

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
MINING ENGINEERING

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Title of Thesis:

STUDYING THE EFFECT OF DIFFERENT ADDITIVES ON PHYSICAL AND MECHANICAL PROPERTIES OF MORTARS

Key Words:
Mortars; Additives; Mechanical properties; XRD; SEM

Summary:

The present work is an attempt to improve physical and mechanical properties of lime mortars by preparing mortars with adding different additives some of them are natural additives like homraa, kosromel and silica fume and the others are artificial additives from Sika Company like sika1, sikabond and sikalite. After preparation mortars, the physical and mechanical properties were measured and the samples were exposed to different environments such as Acid water weathering, Salt crystallization and Wet-dry cycle. This work is reported that polyvinyl alcohol (sikabond) improve physical and mechanical properties more than other tested additives.

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Finally, I present all my work to my father's soul.

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Abstract

Lime mortar is consist of lime and an aggregate such as sand, mixed with water. It is one of the oldest known types of mortars, dating back to the 4th century BC and widely used in Ancient buildings.

Materials used to repair or replace original Ancient buildings should have similar properties so as not to disrupt the balance of interaction within the building.

The present work is an attempt to improve physical and mechanical properties of lime mortars using different additives.

Lime mortar modified with different additives such as [Homraa, Kosromel, Silica fume, sika bond (polyvinyl alcohol), sika 1(polyacrylamide) and sikalite (additive 3)] were prepared. Characterization of materials used in mortar preparation are determined by X-Ray diffraction, Chemical analysis, Zeta potential and FTIR.

Different properties of lime mortars were measured: mechanical properties (such as compressive strength) and physical properties (density, porosity and water absorption). These mortars exposed to different environments such as Acid water weathering (using H_2SO_4), Salt crystallization (using Na_2SO_4) and Wet-dry cycle.

This work is reported that polyvinyl alcohol improve physical and mechanical properties of mortars without cement more than other tested additives. On the other hand when cement added mortar consist of lime, sand, cement and silica fume show high compressive strength than others samples.

Chapter 1 : Introduction

1.1. Background

The traditional lime mortar is consist of lime, sand and water. Besides these constituents it may also contain additives aiming to improve fresh mortar´s workability and/or to improve hardened mortars' strength and durability.
The idea of improving mortar´s properties by using various additives is not new, but something which has been known already by the first civilizations [1, 2]. Lime-based mortars used in ancient times were sometimes of poor quality; therefore masons were employing various additives to reach desired properties. There are records that egg whites, bullock´s blood, fruit juices, keratin and casein were used in Ancient Egypt [3, 4]. Bitumen as an oldest known natural organic additive was used already in Mesopotamia some 4000 years ago [5, 6, 7]. Romans were known to use pozzolanic materials, which were giving hydraulic properties to mortar, but these were not always available and cost was also a large factor [8]. Consequently locally available materials increased in use. Variety of substances of different origin were used, such as local agro products (cereals, juices from trees, fruits and vegetables), oils and fats, milk, eggs, but also blood, dung, urine or other materials like animal hair. Although it looks that almost everything available went into mixes, there seemed to be a method behind their madness [3]. Unfortunately there is not much information in literature about the technology of mortars preparation. This being their live hood, masons were scared to write about the things they knew and often the knowledge and experience were buried with them [6]. On the other side we have legends of excellent durability of some historic mortars, which has been accredited just to the use of natural polymeric additives.
Nowadays it is quite complicated to analyze organic additives in historical mortars since they were probably added in very small amounts which may be under the detection limit of some analytical methods. Thus it is probable that most of the information of using natural polymeric additives is based on the study of historical sources rather than on the exact material analysis of preserved monuments [9].

1.2. Thesis objectives

The research objectives of this thesis are:

- To study the effect of additives on the physical and mechanical properties of lime mortars;
- To experimentally verify the assumption that the addition of these additives are increasing mortar´s resistance to deterioration;
- To develop a mortar with improved durability suitable for restoration.

Chapter 2 : Literature Review

2.1. Definition of mortar

A mortar can be defined as a mixture of one or more inorganic or organic binders, mostly fine aggregates, water and sometimes additives and/or admixtures in the proportions necessary to give to the mixture proper workability in the fresh state and adequate physical and mechanical properties, outward aspect, durability etc., in the hardened state [10].

Mortar can be divided into:

- According to its use as either:
  - Bedding and jointing mortar – to bond masonry units (brick and/or stones) together;
  - Plastering mortar – for external coating of masonry;
  - Rendering mortar – for internal application on masonry; or
  - Stucco – decoration mortar.
- According to binder (or the combination of binders)
  - Clay mortar;
  - Gypsum mortar;
  - Lime mortar;
  - Pozzolanic mortar;
  - Hydraulic lime mortar;
  - Portland cement mortar;
  - Mixed mortars (lime-clay, lime-gypsum, lime-cement...); or
  - Special mortars (water-proofing, desalination, thermo-isolating mortars...).

2.2. Mortar composition

Mortar is composed of a binder, aggregate, water and additives.

2.2.1. BINDERS

In general, the purpose of the binder is to hold the sand particles together and to fill the voids in between the grains of sand [11].

2.2.1.1. TERMINOLOGY ON LIME

According to the standard EN 459-1 [12] on building lime following terms and definitions apply:

Lime - material comprising any physical and chemical forms under which calcium and/or magnesium oxide (CaO and MgO) and/or hydroxide ($Ca(OH)_2$ and $Mg(OH)_2$) can appear.

Building lime - limes used in building construction and civil engineering. They are either air limes or hydraulic limes.

- **Air lime** – lime mainly consisting of calcium oxide or hydroxide, which slowly harden in air by reacting with atmospheric carbon dioxide. Generally, they do not harden under water as they have no hydraulic properties. They may be either quick lime or hydrated lime.
  - **Quick lime (Q) -** air lime mainly consisting of calcium oxide and magnesium oxide produced by calcination of limestone and/or dolomite rock. They have an exothermic reaction when in contact with water. They are offered in varying sizes ranging from lumps to ground powder materials. They include calcium lime and dolomitic lime.
  - **Hydrated lime (S)** - calcium lime or dolomitic lime, resulting from the controlled slaking of quick lime. They are produced in the form of a dry powder or putty or as a slurry (milk of lime).
  - **Calcium lime (CL) -** lime mainly consisting of calcium oxide or calcium hydroxide without any additions of hydraulic or pozzolanic materials.
  - **Dolomitic lime (DL) -** lime mainly consisting of calcium oxide and magnesium oxide or calcium hydroxide and magnesium hydroxide without any additions of hydraulic or pozzolanic materials.
    - **Semi-hydrated dolomitic lime -** hydrated dolomitic limes mainly consisting of calcium hydroxide and magnesium oxide.
    - **Completely hydrated dolomitic lime -** hydrated dolomitic limes mainly consisting of calcium hydroxide and magnesium hydroxide.

- **Hydraulic lime (HL)** lime mainly consisting of calcium hydroxide, calcium silicates and calcium aluminates produced by mixing of suitable materials. They have the property of setting and hardening under water. Atmospheric carbon dioxide contributes to the hardening process.
  - **Natural hydraulic lime (NHL) -** lime produced by burning of more or less argillaceous or siliceous limestone with reduction to powder by slaking with or without grinding. All NHL have the property of setting and hardening under water. Atmospheric carbon dioxide contributes to the hardening process.
  - **Natural hydraulic lime with additional material (Z) -** special products may contain added suitable pozzolanic or hydraulic materials, up to 20 % by mass, are additionally designated by "Z".